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Study on new antenna designs for modern wireless communication system

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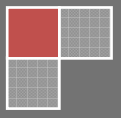
ABSTRACT

The cellular technology and the wireless communication technology is developing and improving rapidly. The antenna acts as the bridge between the user terminal and the base station controller (BSC). Being a vital component of the wireless communication system, the antenna's basic function is to broadcast and to receive electromagnetic waves. It will, to a large extent, affect the quality and the speed of the communication. With the progressing of the antenna technology, the mobile terminal devices have evolved from the original communication tools to highly intellectualized equipments. The communicated content was also diversified, as there are now FM programs, TV shows and internet. All these, however, brings demanding standards to the antenna. For example, it requires a much higher bandwidth and top performances from the antenna to support the complex applications and communication function of the mobile terminals. Besides, the communication system's portable terminal has nearly locked the position of the antenna, which demands that the size of the antenna must be downscaled. The control of the wave velocity, shape and its directivity can be usually optimized by improving the radiation characteristics of the antennas, which will boost the overall performance of a system. In this way, also improved are the channel capacity and the frequency utilization ratio. This paper, beginning with the introduction of the development status of the wireless communication system and the antennas, studies some of the designs of new antennas. With that study, this paper also analyzes the development direction fitting to modern communication system and the relevant devices, as well as the structure adaptation and trend of antennas.

KEYWORDS

Antenna; Modern wireless Communication system; Mobile terminal; Intelligentization.



INTRODUCTION

From the first antenna born out of the experiments of the German, Hertz, the wireless communication system had developed from the middle and long wave ones to the vertical polarized electrically small antenna. Then there are the directive antenna - wave antenna, and the directive transmitting antenna. At the transmitting terminal, the antenna converts the energy from high-frequency current into the radio wave energy of the same frequency. At the receiving terminal, it transforms the high-frequency wave energy into the current energy of the respective frequency. In the WLAN, the antenna's design is the key to a larger system capacity and broader signal coverage. Essentially, the antenna is an energy converter. Being the most rapidly developing section of modern communication system, mobile communication, along with the wireless access communication system, is inseparable with antennas. The advancing of modern wireless communication system pushes the conceptual revolution and tech-innovation of the antenna. Whereas the antenna's evolution will also have its impact on the development of the communication system

BASIC KNOWLEDGE

Wireless communication system

The wireless communication system is a communication method which uses electromagnetic wave to freely spread information across the space. Its development began from the 1930s. Major milestones are: the discover of electromagnetic wave in 1888, the FM theory in 1920, the semiconductor tube in 1960, and CDMA's ratification by the FCC of the U.S. in 1992, and the IUT's standardization of the 3G in 1999 and etc. Below is the TABLE 1, the current radio-frequency spectrum.

TABLE 1: Division of the radio-frequency spectrum

Waveband		Wavelength	Frequency	Mode of Transmission	Main Use
Long wave		30000m~3000m	10kHz~100kHz	Ground wave	Ultra-long range radio communication and navigation
Medium Wave		3000m~200m	100kHz~1500kHz	Ground wave and Sky wave	AM radio broadcasting
Intermediate waves		200m~50m	500kHz~6000kHz		
Short wave		50m~10m	6MHz~30MHz	Sky wave	
Microwave	Meter wave(VHF)	10m~1m	30MHz~300MHz	Approximately rectilinear wave	FM radio broadcasting
	Decimeter wave(UHF)	1m~0.1m	300MHz~3000MHz	Rectilinear wave	Television Radar Navigation
	Centimeter wave	10cm~1cm	3000MHz~30000MHz		
	Millimeter-wave	10mm~1mm	30000MHz~300000MHz		

Modern wireless communication system mainly consists: the 2G mobile cellular network system represented by GSM, IS-95; the 3G by CDMA2000, WCDMA, and TD-SCDMA. It also includes WLAN, WMAX, the radio television system and the satellite communication system.

The communication system can be divided into the analog communication system and the digital transmission system, with the latter replacing the former. The models for the communication system are illustrated in Figure 1 below.

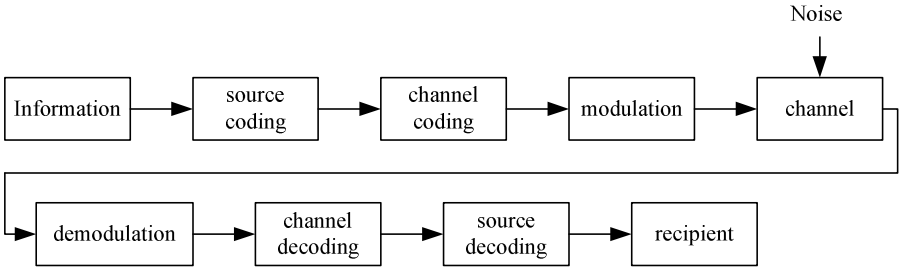


Figure 1 : Model of communication system

Development status of the antenna

With the orientation to serve modern communication devices' improvement, the research on the antenna mainly includes: multiband function, size, adaptive pattern control and broadband and etc. Particularly, modern electronic

equipments' integration has made the communication devices become ever more compact, this reason requires the antennas to be smaller and smaller.

In term of the current technology, it is a tremendous task to compact the antennas without diminishing its function. For the time being, aboard there are many researches being put forward, to downsize the volume of the antenna, such as to attach a parasitic patch to the radiation patch[1]; or to apply a F-shaped micro strip patch[2]; or a Coplanar waveguide resonant unit[3].

The increase of integration of electronic equipment usually demands that the antenna can provide two or more wireless service in a broad frequency range. The broadband antenna and the multiband antenna are qualified to such a demand. This, however, results in the complexity of the type of antenna. The kinds of the CPW-fed antenna and the planar monopole antenna[4,5] have become the focus of study. The TABLE 2 below shows the major types of the antennas of today.

TABLE 2: Major types of antennas

Name	Description
2.4GHz miniaturized micro-strip antenna	Supplied with micro-strip wires, coaxial wires or other feeders, this type of antenna creates electromagnetic field between the metal patch and the earth plate. It is now commonly applied on radio equipments of broad frequency ranges, such as airborne or portable devices.
Ultra-wideband antenna (UWB)	With signal broadband of 500MHz or more. Mainly spherical antennas, ellipsoidal monopole or bi-conical antennas. At early periods it was used mainly in military systems.
Conical antenna	An antenna used widely in ultra-wideband EMPs
TEM horn antenna	The main form of UWBs. Constructed mainly by two triangle panel and other components.
Diagonal spiral antenna	This antenna's performance is not closely linked to its frequency. Its diagonal angle determines the structure, and they are one beamed, two beamed or four beamed.
Log-periodic antenna	This antenna's performance adjusts periodically along with the logarithms of its frequency.
Planar monopole antenna	A new type of UWBs. Characterized by a high degree of integration and compactness. It adopts mainly the structure of round disk, elliptical disk or planar square[8], but requires a vertical floor to support it.
Diversity antenna of MIMO system.	Still being developed. Exclusively designed for portable devices like the cell-phone and others[9].

THREE TYPES OF NEW ANTENNA DESIGNS.

Mini micro-strip antenna

As an antenna currently applied widely on the radio equipments of 100MHz~100GHz's frequency domain, the micro-strip antenna employs micro-strip patch as its radiation source. Being compact and light-weighted, it can also ingrate into a system with active device and electric circuits. Up till now, micro-strip antenna's experimental and computing methods are both ripe.

In general, the miniaturization of the antenna means only to downsize its volume, and to leave its working frequency intact. The passage below is the concrete schemes for the miniaturization, shown in TABLE 3.

TABLE 3 : Schemes for the miniaturization of micro-strip antennas

Schemes	Detailed Description
Increase the dielectric constant	Micro-strip antennas of the half-wave radiation design usually work on the TM10 or TM01 model, their resonant frequency being: $f = c / 2L(\varepsilon_r)^{1/2}$ (c: the speed of light, L: length of the patch, ε_r: relative dielectric constant). Because the resonance length is inversely proportional to the $(\varepsilon_r)^{1/2}$, the best way to downsize the radiation device is to use materials of greater dielectric constant. On the other hand, such material is limited by the transmission gain of the micro-strip antenna.
Load technology	Mainly the resistor loading and the short-circuit loading. The short-circuit loading can be divided into three types: loading the short-circuit probe, loading the short-circuit plate, and loading the short-circuit plane. The last method can reduce half of the length, and the probe method can further reduce 30% than that. Because of the characteristics of the antenna under the resonant frequency, we can further reduce the frequency and the size by adding a loading resistor near the coaxial feeder point.
Extend the surface current path.	Another effective way to reduce the antenna size. It is based on the earth plate and the patch meandering technology. To extent the effective surface current path, it slots the non-radiation side of the patch.
PIF, PIL structure	Exclusively aimed at the antennas that is coaxial fed and use the air layer as the medium, this method solves the coaxial impedance effect. Its basic modes include the L-shaped probe technology and the L-shaped micro-strip line feeding.

Ultra-wideband Antenna

Ultra-wideband antenna mainly applies to short range radio communication system with features of strong anti-multipath effect, wide bandwidth and low power,[10], thus making ultra - wideband antenna research highpoint。Ultra-wideband antenna, commonly known as the antenna with very wide bandwidth, is capable of sending picoseconds or nanoseconds narrow-band signals. Technology features of ultra-wideband antenna are mainly as follows:

(1) Tiny reflection and allows UWB antenna have a good input impedance matching within working frequency bandwidth;
(2) The antenna frequency bandwidth should meet the demands of 3.1GHz to 10.6GHz;
(3) High standard of non-dispersion characteristic and difficulty of antenna design increases;
(4) Very small volume;
(5) Radio efficiency should guarantee the effect of Omni-direction, and should be high and stable;
(6) Power pattern in each frequency bin should be nearly same and has stable gain.

Broadband polarization diversity antenna

As an effective communication technology, diversity technique compensates for channel fading and thus becomes research highpoint with the development of mobile communication technology. The feature of diversity technology is to choose the best signal, receive the sample signal through various means and then combine and classify them. The implementation process of this technology cost little and doesn't need to increase the transmission power or bandwidth. At present, main classification of diversity antenna are shown in TABLE 4.

TABLE 4 : Diversity antenna classification

Classification rules	Names	Function description
According to the purpose of diversity.	Macro diversity	Purpose of which is to resist slow fading. Generally speaking, Two antenna sites are needed to send and receive two or more signals, in order to avoid signals sent by center being cut off by high points such as mountainside, thus the mobile station couldn't receive the signals.
	Micro diversity	Purpose of which is to resist fast fading. The technology belongs to one antenna site.
According to ways of receiving independent path signals	Space diversity	It is among the most common forms which use several separate antennas in the space. Though it's easy to be done but it needs a lot of space. The advantage of this method is to receive several samples from emission signal without occupying extra frequency resources.
	Frequency diversity	It actually transmits signals through different frequencies, which could gain the multi-path benefit in communication environment.
	Angle diversity	Also known as pattern diversity, which separates signals of different directions through different pattern directions.
	Polarization diversity	The method of achieving diversity gain is to receive orthogonal planning components. It applies to terminal equipment with strict demands of volume because of its small overall volume.
	Time diversity	It integrates interweaving technology and channel coding, which allows receiving terminal to receive several samples from emission signal simultaneously.

CONCLUSIONS

This paper introduces the development status of the wireless communication system and the basic research direction of antenna; then it mainly analyzes several antenna modes of wireless communication system. These antennas all designed based on the rules of miniaturization. The antenna mainly applies flat structure for the convenience of integration and miniaturization of mobile terminal. To meet the development of modern communication system and relevant equipment, new antennas with high performance has developed rapidly. However, only by breaking through current technology limitations and defects can the new antennas be fully developed in aspects of technology, products and standardization. Combined with communication industry, the mature and application of new type of antenna need concerted effort. In terms of new antennas, undoubtedly, there are many technology difficulties to overcome. For example, multi-standard antenna could flexibly control signals with different patterns by solving the problem of mutual interference of different signals; To solve this problem, equipment support such as high-performance phase shifter and combiner with high isolation is needed; and the intelligent antenna faces technology difficulties of realizing remote control technology and antenna beam scanning more than one dimension; active integrated antenna must breakthrough the limitation of existing device volume and performance, and applies radio frequency devices with multiple frequency ranges in antenna system, in order to integrate RF module and antenna module.

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